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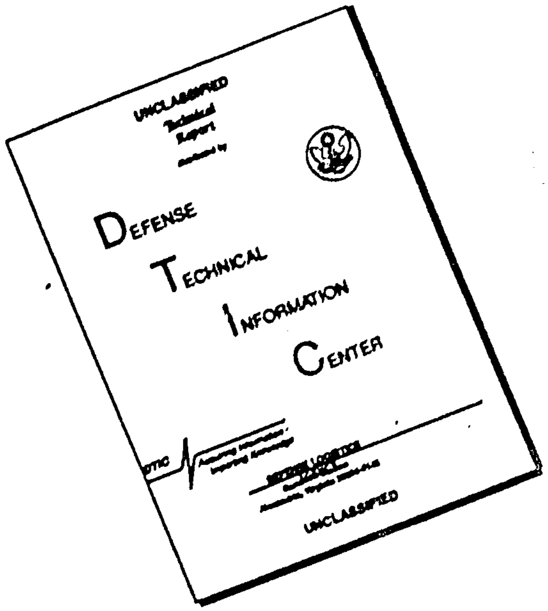

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AID Report 61-124

31 August 1961

TRACKING OF MISSILES AND SPACE VEHICLES

REVIEW OF SOVIET LITERATURE

AID Work Assignment No. 12

Report No. 13

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Science and Technology Section

Air Information Division

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The publication of this report does not constitute approval by any U. S. Government organization of the inferences, findings, and conclusions contained herein. It is published solely for the exchange and stimulation of ideas.

Science and Technology Section

Air Information Division

SUBJECT: Monthly Report - AID Work Assignment No. 12

PERIOD : July-August 1961

This is the thirteenth in a monthly report series reviewing Soviet development in tracking missiles and space vehicles. It is based on source materials received at the Air Information Division during July and August 1961. Information not directly related to the assigned subject has been included because of its broad implications for study in this field.

The materials in this report deal with the following topics:

II. Ion clouds and ionosphere perturbations
V. Radio Astronomy

SUBJECT: Monthly Report - AID Work Assignment No. 12

PERIOD: July-August 1961

TOPIC II. ION CLOUDS AND IONOSPHERE PERTURBATIONS

1.) Gurevich, A. V. Perturbations in the ionosphere caused by a moving body. IN: Akademiya nauk SSSR. Institut zemnogo magnetizma, ionosfery i rasprostraneniya radiovoln. Trudy, no. 17(27). Rasprostraneniye radiovoln i ionosfera. Moskva, 1960, 173-186.

Ionospheric perturbations caused by rockets and satellites are considered in terms of the interaction of a moving body with ions and electrons. Since the effect of the body on these particles is different there is a difference also in the perturbation of electron and ion densities. The quasi-neutrality of the plasma is disturbed and the disturbance is accompanied by the occurrence of an electric field. Both the variation in density of neutral particles near the surface of the body and the variation in density of electrons and ions are examined, and the magnitude of the electric field which affects the distribution of particles is determined. Because the velocity of bodies moving in the ionosphere ($v_o \approx 10^6$ cm/sec) is considerably higher than the thermal velocity of molecules and ions ($v_m \approx 10^5$ cm/sec) but lower than the thermal velocity of electrons ($v_e \approx 10^7$ cm/sec) it is assumed that the following inequality is satisfied:

$$\sqrt{kT/M} < v_o < \sqrt{kT/m}, \text{ where}$$

T is the gas temperature, M is the mass of a molecule, and m is the mass of an electron.

1. Density of neutral particles

In the case of a sphere with a radius of R_o moving in a gas at supersonic speed, it is assumed that there is a specular reflection of particles from the surface of the sphere. In the process of particle collision with the body a rarefied, low-density, region is formed behind the body and a high-density region in front of it. If the process lasts long, i.e. if $\Delta t \gg R_o/v_o$, a steady-state distribution of particles occurs. The following expression is derived for the excess density of particles in the high-density region. i.e., the density which results from the presence of particles reflected from the sphere and which is additional to the gas density encountered by the sphere:

$$n_{m_1} = n_{m_o} \frac{R_o^2 \sin^2 \theta_1 \cos^2 \theta_1}{r^2 \left(1 - \frac{R_o}{r} \sin^3 \theta_1\right)}$$

where n_{m_1} is the excess density, n_{m_o} the density of the gas encountered by the sphere, θ_1 the angle between the normal to the sphere at the point of collision and the horizontal axis, and $r = R_o \sin\theta_1$. With the use of this expression it is shown that the density of molecules in the high-density region varies considerably. At the surface of the body the relative density n_{m_1}/n_{m_o} is 100%; at a distance of [illegible] R_o from the body's surface, $n_{m_1}/n_{m_o} \approx 50\%$; at 0.5 R_o, $n_{m_1}/n_{m_o} \approx 20\%$; and at R_c, $n_{m_1}/n_{m_o} \approx 10\%$. In the case of a nonspecular reflection, i.e., a diffusion reflection, the excess density was found to be $n_{m_1} \approx n_{m_o} \frac{1}{2} \ln(2R_o/\Delta R)$ where ΔR is the distance from the surface of the sphere. To determine the density of particles in the rarefied region, account is taken of the velocity distribution of particles. Under the assumption of a Maxwellian distribution, the following expression is derived for the density:

$$n_m = n_{m_o} \exp\left\{-(R_c/Z)^2 \, (Mv_o^2/2kT)\right\}.$$

2. Density of ions and electrons and the electric field

Solution of a system of equations consisting of a kinetic equation for ions and electrons and an equation for the electric field shows that the density of electrons near the moving body is approximately equal to the density of ions. Expressions are also obtained for equipotential surfaces around the moving body The above discussion is limited to cases where the surface of the moving body is a dielectric which reflects totally all particles. In the case of a metallic surface, electrons are absorbed by the surface and ions are neutralized, at least partially. Comparison of the distribution of equipotential surfaces around a dielectric body with that around a metallic body shows a difference in distribution only near the body. The maximum value of the electric field potential is of the same order of magnitude; it occurs, however, not near the body's surface but at a distance of approximately R_o.

2.) Benediktov, Ye. A., and V. Ya. Eydman. Incoherent radio emission occurring during the motion of charged particles in the earth's magnetic field. Izvestiya vysshikh uchebnykh zavedeniy. Radiofizika, v. 4, no. 2, 1961, 253-258.

Radiation of an electron moving in a magnetoactive plasma may be divided into two components, a Cherenkov and a synchrotron component. The former predominates when $v_{\parallel}/v_{\perp} \gg 1$, while the latter prevails when $v_{\parallel}/v_{\perp} \ll 1$ and $(v_{\perp}/c)n_j(\omega,\theta) \ll 1$, where $v_{\parallel}$ and $v_{\perp}$ are, respectively, the parallel and the perpendicular component of the velocity of a particle with respect to the magnetic field and $n_j(\omega,\theta)$ is the refractive index of the j-th normal wave. For evaluation of the intensity of the electron radio emission in the medium-frequency band, both the Cherenkov radiation and the synchrotron radiation are discussed separately.

Cherenkov radiation. In this discussion a stream of charged particles with a density ρ and moving with a constant velocity v is assumed. The cross-sectional dimensions of the stream are large so that the edge effects may be disregarded. The reabsorption of radiation of particles is also disregarded on the assumption that the intensity of total radiation is a sum of the intensities of radiation of individual particles. Under such conditions, the intensity of the Cherenkov radiation averaged within a half sphere may be determined from the following expression:

$$J = \frac{1}{2\pi} \int_{z_1}^{z_2} q v_{\parallel} \; w dz,$$

where w is the intensity of radiation of a charged particle in a unit path, z_1 and z_2 are the limits of integration which are determined from the condition $\cos^2 \vartheta \leqslant 1$ (ϑ being the angle between the direction of propagation of the radiated wave and the direction of the magnetic field). On the basis of the above expression and under the assumption that 1) $z_2 - z_1 = \Delta z = 100$ km; and 2) $\beta^2 = (v_{\parallel}/c)^2 = 0.004$, the intensity of radiation at a frequency of 0.5 mc and at an altitude of approximately 1500 km was determined as $J = 5 \times 10^{-20}$ $q \cdot watt \cdot m^{-2} \cdot cps^{-1} \cdot steradian^{-1}$. With $\Delta z = 300$ km and $\beta^2 = 0.01$, J was found to be $6 \times 10^{-19} q \cdot watt \cdot m^{-2} \cdot cps^{-1} \cdot steradian^{-1}$.

Synchrotron radiation. The frequency of the synchrotron radiation caused by nonrelativistic particles is determined by the intensity of the magnetic field. Each altitude in the earth's atmosphere corresponds to a certain generation frequency $\omega = s\,\omega_H$ (ω_H being the gyrofrequency and $s = 1,2,3\ldots$); the intensity of harmonics, beginning with the second harmonic, decreases with an increase in s. The evaluation of the radiation intensity is limited to a case where $(n_2\beta_\perp)^2 < 1$; the intensity is expressed as follows:

$$I_{sj} = \frac{e^2(\omega)^2 \; n_j \; |\xi|^2 \; v_\perp^2}{4\pi c^3} (1 + \alpha_j)^2 \frac{y^{2(s-1)}}{2^{2s}[(s-1)!]} \, d\Omega$$

where $y = n_j \beta_\perp \sin\vartheta$, $d\Omega$ is the element of the solid angle, and α_j and ξ_j are the parameters characterizing the polarization of normal waves propagating in a magnetoactive plasma. With the above expression and under the assumption that $\beta_\perp^2 \approx 0.3$ and $\vartheta \approx 10°$ the intensity of synchrotron radiation at an altitude of approximately 1500 km and at plasma frequency $\omega_0 \approx 10^7$ was determined as approximately $10^{-20} q \cdot watt \cdot m^{-2} \cdot cps^{-1} \cdot steradian^{-1}$. With $\omega_0 = 3 \times 10^{11}$, $\beta_\perp \approx 0.3$ and $\vartheta = 20°$, the intensity at an altitude of 3000 km was found to be 10^{-22} $q \cdot watt \cdot m^{-2} \cdot cps^{-1} \cdot steradian^{-1}$. The above values are not claimed to be accurate. They show the order of mangitude only. The decrease in radiation intensity at 3000 km as compared with the intensity at 1500 km is explained by a sharp decrease in $(1 + \alpha_j)^2$, a factor which depends on the nature of polarization of normal waves propagating through the ionosphere. (Gor'kiy Scientific Research Institute of Radiophysics)

3.) Akhiyezer, A. I., A. B. Kitsenko, and K. N. Stepanov. On the interaction of beams of charged particles with low-frequency plasma oscillations. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 40, no. 6, Jun 1961, 1866-1870. QC1.Z47

In a study of the interaction of a beam of charged particles with low-frequency, primarily magnetoacoustic, waves in a plasma, in the presence of a constant magnetic field acting in a direction parallel to the motion of the beam, the assumption is made that the beam density is much lower than the plasma density and that the thermal scattering of electrons in the beam is small. Under this assumption, a dispersion equation describing the magnetoacoustic waves is solved and it is shown that if the electron temperature is much higher than the ion temperature the plasma-beam system is unstable because of the interaction of the magnetoacoustic waves with the beam. When the electron temperature is lower than or equal to the temperature of ions the instability occurs only when the natural plasma oscillations become strongly attenuated. It is also shown that, in general, a beam of particles with low density and high thermal scattering of electrons and ions does not generate magnetoacoustic waves in a plasma. (Physicotechnical Institute, Academy of Sciences Ukrainian SSR)

SUBJECT: Monthly Report - AID Work Assignment No. 12

PERIOD: July-August 1961

TOPIC V. RADIO ASTRONOMY

1.) Benediktov, Ye. A., and G. G. Getmantsev. Sporadic solar radio emission at low frequencies. Izvestiya vysshikh uchebnykh zavedeniy. Radiofizika, v. 4, no. 2, 1961, 244-252. QC661.R8

In the summer of 1959 and 1960, studies were conducted for the purpose of registering solar flares at frequencies of 25, 18, 13, and 10.5 mc. For the first three frequencies, the antenna systems consisted of multidipole cophased arrays suspended at a height of $\lambda/4$ above metal-covered ground. The radiation patterns of these antennas were identical; the width of the major lobe at half-power points was 30° x 30°. At 10.5 mc, reception was carried out with the aid of either a horizontal rhombic antenna, having a narrow directional pattern in the horizontal plane, or a half-wave dipole. Standard receivers with an intermediate-frequency bandwidth of 3 kc were used. The time constant of the receiver output circuit containing a pulsed noise limiter was about 0.5-1 sec during decrease in signal magnitude and several tens of seconds during increase. Sporadic radio emission and a considerable number of solar flares were observed in the 25 to 10.5-mc frequency range. The intensity of solar flares was high in the entire experimental frequency range, but evaluation of the intensity was possible only at a frequency of 10.5 mc. Under the assumption that the effective temperature of the galactic background at this frequency is several hundred thousand degrees, the intensity was determined to be as high as 10^{-19} w/m^2. cps. It is believed that solar flares occur also at frequencies lower than those used in the study.

2.) Kashcheyev, B. L., M. F. Lagutin, and I. A. Lysenko. Study of individual radiants of the Geminid showers. IN: Akademiya nauk Ukrayins'koyi RSR, Dopovidi, no. 5, 1961, 623-626. Q60.A7

Since December 1958, a special system has been used which makes it possible to measure orbits and velocities of meteor particles as well as the velocity and the direction of motion of ionized wakes by recording signals reflected from meteor trials at three different points on the surface of the earth. The system consists of a high-power pulse transmitter and a high-sensitivity receiver which operate on an 8-m wavelength. The other two receivers are placed at a distance of 4 and 8 km from the main receiving station. Signals received at these points are relayed to the main station and recorded. Analysis of the data obtained on the position of the radiants and on meteor velocities for the 1959 Geminid showers shows good agreement with the results obtained in other studies. It was found that the accuracy of determining the radiants of individual meteors is affected by the action of turbulent winds in the meteor zone. The meteor velocity in the Geminid showers above the earth's atmosphere was determined as 36.1 km/sec. It was was also found that the error in recording the radiants of meteors moving with a velocity of 35 km/sec is ± 3° and the error of determining the velocity is ± 1.5 km/sec. (Khar'kov Polytechnic Institute)

3.) Bel'kovich, O. I. Determination of the mean-square error of the number of meteors observed in a unit of time. Astronomicheskiy zhurnal, v. 38, no. 3, 1961, 532-535. QB1.A47

An expression for the mean-square error of number of meteors observed in a unit of time is derived and experimentally verified. It is shown that the time distribution of meteors follows Poisson's equation and that the mean-square error of the number of meteors observed in a time unit depends on the total number of meteors observed and the length of observation. In order to detect possible meteor showers, consideration is also given to a method based on the dispersion analysis for preliminary determination of [redacted] meteor activity. (Astronomical Observatory imeni Engel'gardt)

4.) Kislyakov, A. G. Results of an experimental study of lunar radio emission in the 4-mm wavelength range. Astronomicheskiy zhurnal, v. 38, no. 3, 1961, 561-563. QB1.A47

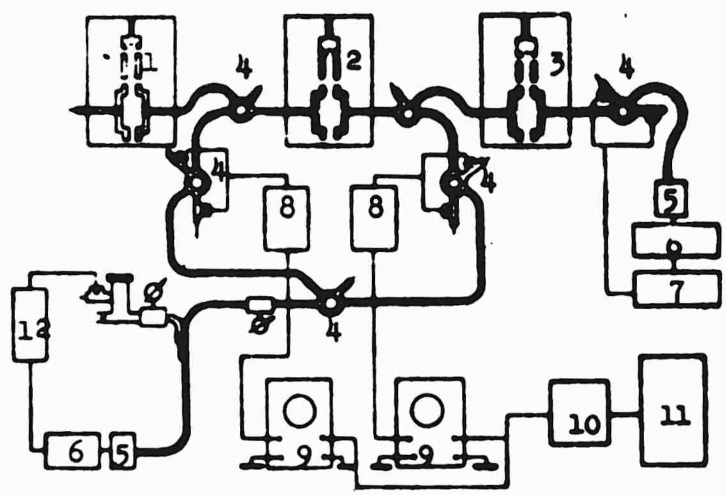
An experimental study of lunar radio brightness on the El'brus mountain (3150 m above sea level) was conducted in the summer of 1960. A radio telescope consisting of a parabolic image antenna with a beamwidth of 25' and a radiometer operating in the 4-mm wavelength range were used. The observations made it possible to obtain a curve showing the variation in intensity of lunar radio emission with the phase of the moon. The curve, having an almost sinusoidal shape, may be approximated by the following expression: $T = [230 + 73 \cos(\Omega t - 24°)]$ where T is the radio temperature of the moon in °K and Ω is the lunation frequency. The accuracy of measurement was ±15%. (Gor'kiy Scientific Research Institute of Radiophysics)

5.) Basov, N. G., V. V. Nikitin, and A. N. Orayevskiy. Study of the dependence of maser frequency on various parameters. Part I. (Theory. Line J = 3, K = 2). Radiotekhnika i elektronika, v. 6, no. 5, 1961, 796-805. TK7800.R4

A study is reported on the feasibility of the ammonia maser as an absolute frequency standard with an accuracy of 10^{-10}. An attempt was made to derive the frequency characteristic based on an approximation of the actual velocity distribution. Particular attention was given to maser frequency dependence on the natural frequency of the cavity, uneven molecular emission along the cavity, hyperfine structure effects, and pressure changes. The experiments were carried out with ammonia masers utilizing the J = 3, K = 2 line and featuring two opposed beams to improve the oscillation characteristics and to compensate for the uneven molecular emission along the axis of the cavity. The cavity with the power take-off in the center, was 11.2 cm long, yielding the E_{010} mode; a tuning range of several megacycles was achieved through a liquid nitrogen cooled diaphragm with an aperture of 0.6 cm. It was found that an opposed-beam maser has a point on the cavity frequency characteristic where the maser frequency does not depend on pressure. The opposed-beam principle also yields a frequency characteristic where the maser frequencies plotted at equal intervals against pressure and sorting voltage are symmetrical with respect to the resonance line. Two masers with opposed beams could be tuned to the spectrum line frequency with an error of 3 cps. It is noted that while these experiments were made with $N^{14}H_3$ gas, a more detailed investigation should be attempted with $N^{15}H_3$ gas because of the wider range of parameter variation possible in the latter case. The conclusion is reached that a maser utilizing two identical and opposed beams and a symmetrical design can serve as an absolute standard of frequency with an accuracy of 10^{-10}. (Physics Institute imeni P. N. Lebedev, Academy of Sciences, USSR)

6.) Basov, N. G., G. M. Strakhovskiy, and I. V. Cheremiskin. Study of the dependence of maser frequency on various parameters. Part II. Line J = 3, K = 3. Radiotekhnika i elektronika, v. 6, no. 6, 1961, 1020-1028. TK7800.R4

In order to analyze the tuning accuracy and frequency stability of a molecular oscillator, several experiments were conducted to determine the effect of cavity tuning, sorting voltage, and pressure in the beam source on maser frequency. In the setup used for measuring maser frequency (see illustration),



Block diagram for measuring maser frequency

1,2, and 3 - masers; 4 - hybrid rings; 5 - klystron oscillator; 6 - klystron power supply; 7 - intermediate-frequency amplifier and an oscillograph; 8 - intermediate-frequency amplifiers and second detectors; 9 - oscillographs; 10 - audio-frequency oscillator; 11 - frequency meter; 12 - 75-kc amplifier and a discriminator frequency measurements were made by comparing three masers in pairs whose frequency differed by several hundred cps. The output of each pair was first mixed in a hybrid ring and then fed to a second ring. The latter was used as a mixer of the maser signal with that of a klystron oscillator which was tuned to 23,830 mc, i.e., 40 mc lower than the maser frequency. The output of the mixer was fed to an intermediate amplifier with a gain of 10,000 and bandwidth of 2 mc. The i-f signal with a frequency equal to the difference between the frequencies of two masers was then fed to an oscillograph and measured. The masers used in the experiments had cavity resonators 80 mm in length operating with the E_{010} mode. The resonators, made of invar, had a Q of 6000-8000. They were tuned by means of a stub 2 mm in diameter. The resonator temperature was maintained with an accuracy of 0.01°C; a change in temperature by 0.01°C changed the maser frequency by 1 cps. The results showed that the change in pressure in the beam source from 1.5×10^{-2} to 5×10^{-2} mm Hg changes the maser frequency by 15 cps; the change in sorting voltage by 1 kv changes the frequency by 5 cps; and the change in temperature by 1°C changes the frequency by 100 cps. Therefore, to obtain a long-term maser frequency stability of $\Delta f/f = 10^{-11}$ it is necessary to maintain the following accuracy range for the above parameters:

1. Beam source pressure, 1%
2. Sorting voltage, 0.2%
3. Resonator temperature, 0.002°C.

Since the maser frequency depends less on the change in sorting voltage than on pressure, the latter may be used in tuning, although both types of tuning (variation either in voltage or pressure) can provide for a tuning accuracy on the order of 10^{-8}. Still better tuning accuracy can be achieved by using an opposed-beam maser. (Physics Institute imeni P. N. Lebedev, Academy of Sciences, USSR).

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